HUC 07140101 – Cahokia-Joachim
Water body ID: 1746
Pollutants: Low dissolved oxygen, ammonia, organic sediment

Revised
Total Maximum Daily Load
for
Big Bottom Creek
Ste. Genevieve County

Pollutants of concern: Low Dissolved Oxygen, Ammonia, and Organic Sediment

Submitted: November 15, 2019
Approved: May 15, 2020

Prepared by: Water Protection Program, Watershed Protection Section

WATER BODY SUMMARY
Total Maximum Daily Load (TMDL) for Big Bottom Creek
Pollutants: Low dissolved oxygen, Ammonia, and Organic Sediment

Name: Big Bottom Creek
Location: Near Grayhawk in Ste. Genevieve County

8-digit Hydrologic Unit Code (HUC):[1]
07140101 – Cahokia-Joachim

12-digit HUC Subwatersheds:
071401010907 – Headwaters Establishment Creek

Water Body Identification Number (WBID) and Hydrologic Class:[2]
WBID 1746 – Class C

Designated Uses:[3]
Irrigation
Livestock and wildlife protection
Human health protection
Warm water habitat (aquatic life)
Secondary contact recreation

Impaired Use:
Warm water habitat (aquatic life)

Pollutants Identified on the 2008 303(d) List:
Low dissolved oxygen, Ammonia, Organic Sediment

Identified Source on the 2008 303(d) List:
Lake Forest Estates Subdivision Wastewater Treatment Facility

Length and Location of Impaired Segment:
1.5 miles from mouth (the confluence with Indian Creek) to Lake Anne

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[1] The U.S. Geological Survey uses a nationwide system based on surface hydrologic features to delineate watersheds. This system divides the country into 2,270 8-digit hydrologic units (USGS and NRCS 2013). A hydrologic unit is a drainage area delineated to nest in a multilevel, hierarchical drainage system. A hydrologic unit code is the numerical identifier of a specific hydrologic unit consisting of a 2-digit sequence for each specific level within the delineation hierarchy (FGDC 2003).

[2] For hydrologic classes see 10 CSR 20-7.031(1)(F). Class C streams may cease flow in dry periods, but maintain permanent pools that support aquatic life.

[3] For designated uses see 10 CSR 20-7.031(1)(C) and 10 CSR 20-7.031 Table H. Presumed uses are assigned per 10 CSR 20-7.031(2)(A) and (B) and are reflected in the Missouri Use Designation Dataset described at 10 CSR 20-7.031(2)(E).

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1. Introduction

The Missouri Department of Natural Resources in accordance with Section 303(d) of the federal Clean Water Act is establishing this total maximum daily load (TMDL) to address low dissolved oxygen, ammonia, and organic sediment pollutants in Big Bottom Creek near Grayhawk in Ste. Genevieve County. This Revised TMDL supersedes the TMDL, established by the U.S. Environmental Protection Agency (EPA) on October 26, 2010, that was developed to meet the milestones of the 2001 Consent Decree, *American Canoe Association, et al. v. EPA*, No. 98-1195-CV-W in consolidation with No. 98-4282-CV-W, February 27, 2001. Big Bottom Creek was listed as impaired for protection of aquatic life (now designated "warm water habitat") on the Missouri 2002 303(d) List for biochemical oxygen demand and volatile suspended solids. On the combined 2004/2006 303(d) List, these pollutants were changed to low dissolved oxygen and organic sediment. On the 2008 303(d) List, ammonia was added as a pollutant contributing to impairment. The primary source of these pollutants is the Lake Forest Estates Subdivision Wastewater Treatment Facility, Missouri State Operating Permit number MO-0035742.

Section 303(d) of the federal Clean Water Act and Title 40 of the Code of Federal Regulations (CFR) Part 130 require states to develop TMDLs for waters not meeting applicable water quality standards. Missouri's Water Quality Standards at Title 10 of the Code of State Regulations (CSR) Division 20 Chapter 7.031 consist of three major components: designated uses, water quality criteria to protect those uses, and an antidegradation policy. The purpose of a TMDL is to determine the loading capacity of a specific pollutant that a water body can assimilate without exceeding the applicable water quality standards for that water body. The TMDL process quantitatively assesses impairment factors so that water quality-based controls can be established to reduce pollutant loading and to restore and protect the quality of Missouri's water resources. Based on the relationship between pollutant sources and in-stream water quality conditions, a TMDL is the sum of a wasteload allocation and a load allocation (40 CFR 130.2) with a margin of safety (Clean Water Act section 303(d)(1)(C)). The wasteload allocation is the fraction of the loading capacity apportioned to existing or future point sources. The load allocation is the fraction of the loading capacity apportioned to existing or future nonpoint sources and natural background. The margin of safety is a portion of the TMDL that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality (40 CFR 130.7), any uncertainty associated with the model assumptions, and data inadequacies.

2. Rationale for Revision

Greater understanding of the water body characteristics of Big Bottom Creek warrant a reevaluation of the impairment and the conditions for which water quality standards can be attained. Advances in geographical information systems and additional information sources that have become available in the decade since the development of the original TMDL provide an opportunity to make such a reevaluation. No new water quality data have been collected from Big Bottom Creek since 2009; however, review of the 2010 QUAL2K model indicates the need for significant changes in some modeling assumptions and data inputs to create a better representation of actual stream hydrology and improve predictive ability. Additionally, this revision provides opportunity for inclusion of specific authorization provisions for post-TMDL water quality trading. Such an authorization was not explicitly provided in the original TMDL document.

The 2010 Big Bottom Creek TMDL established total nitrogen and total phosphorus wasteload and load allocations based on EPA Level III Ecoregion 39 criteria (USEPA 2000). However, the

Ecoregion 39 nutrient criteria targets were developed based on streams in pristine or near-pristine environments, and may not be representative of more localized reference conditions. The targets are not tied to specific biological conditions or Missouri's minimum dissolved oxygen criterion. Additionally, these federally recommended nutrient criteria use a statistic-based distributional approach that has little or no linkage to biological "cause and effect" responses or ecologically significant thresholds, and merely represent an administrative water quality protection policy that guides EPA's clean water programs. For these reasons, these targets may not be appropriate metrics for use as wasteload allocations for point source discharge from wastewater treatment facilities. The Department has revised the Big Bottom Creek TMDL based on critical low flow dissolved oxygen data and has established pollutant targets that are proportionate to the existing land uses and geomorphic characteristics of Big Bottom Creek and its contributing watershed. The pollutant targets in the revised TMDL have been established such that the 5.0 milligrams per liter (mg/L) minimum criterion for dissolved oxygen will be achieved, as well as appropriate specific criteria associated with ammonia toxicity, and will ensure conditions are consistent with Missouri's general narrative water quality criteria. Such targets will result in restoration of the protection of warm water habitat (aquatic life) designated use in Big Bottom Creek and will be protective of downstream uses.

The targets and information provided in this revised TMDL replace those found in the 2010 TMDL. The ultimate endpoint for this revised TMDL will be to meet Missouri Water Quality Standards through attainment of the minimum dissolved oxygen criterion for the protection of aquatic life in warm water habitats of 5.0 mg/L and ammonia nitrogen criterion based on temperature and pH as outlined in 10 CSR 20-7.031 Table B2. Compliance with these criteria will be determined in accordance with Department assessment procedures for Clean Water Act sections 305(b) and 303(d) reporting. All pollutant reductions necessary to achieve the TMDL targets calculated in this revised TMDL shall be implemented until such a point that water quality standards are attained. If all point source and nonpoint source pollutant targets are achieved, but water quality standards are not attained, then additional monitoring will be scheduled and the TMDL may be further revised.

3. Water Body and Watershed Descriptions

Big Bottom Creek is located in eastern Missouri within the Cahokia-Joachim subbasin, which is catalogued by the U.S. Geological Survey (USGS) as the 8-digit hydrologic unit code (HUC) 07140101. Big Bottom Creek is a 1.5 mile[4] long stream located in the Headwaters Establishment Creek 12-digit HUC (071401010907) subwatershed, which drains approximately 55 square miles. Big Bottom Creek is identified as water body ID (WBID) 1746 in Missouri's Water Quality Standards. The Big Bottom Creek subwatershed is approximately 4.62 square miles. However, Big Bottom Creek is impounded by Lake Anne (previously called Lake Forest), an 81-acre reservoir surrounded by the Lake Forest Estates Subdivision. Lake Anne splits the Big Bottom Creek watershed into two parts. The upper 4.13-square mile watershed drains to Lake Anne and the lower 0.49-square mile watershed receives seasonal overflow from Lake Anne and runoff from the area below Lake Anne. The impaired segment of Big Bottom Creek originates at the Lake Anne dam overflow, and flows north to Indian Creek (WBID 1747), which is a tributary of Establishment Creek (WBID 1739) (Figure 1). The Lake Forest Estates Subdivision Wastewater Treatment

[4] The EPA-approved 2008 Missouri 303(d) List of impaired waters identified the impaired segment of Big Bottom Creek at a length of 1.9 miles. Due to the increased accuracy of Geographic Information System (GIS) data layers for analysis over previous methods of stream length measurements, the water quality standards (Table H) and the TMDL analyses have been revised such that the impaired segment is 1.5 miles in length.

Facility is the only point source in the lower Big Bottom Creek watershed and is the only source of flow in lower Big Bottom Creek during critical low flow conditions (typically July and August).

The dam for Lake Anne is less than 0.2 mile upstream of the Lake Forest Estates Subdivision Wastewater Treatment Facility outfall. When Big Bottom Creek was assessed for the 1998 Missouri 303(d) List, there was no upstream flow, and the poor condition of the stream was believed to be caused by the facility alone. In April 2005, all inspections found that water from the lake was not contributing to the impairment. Water only runs over the lake spillway during high flow periods. Otherwise, there is no flow in Big Bottom Creek below the dam upstream of the facility.

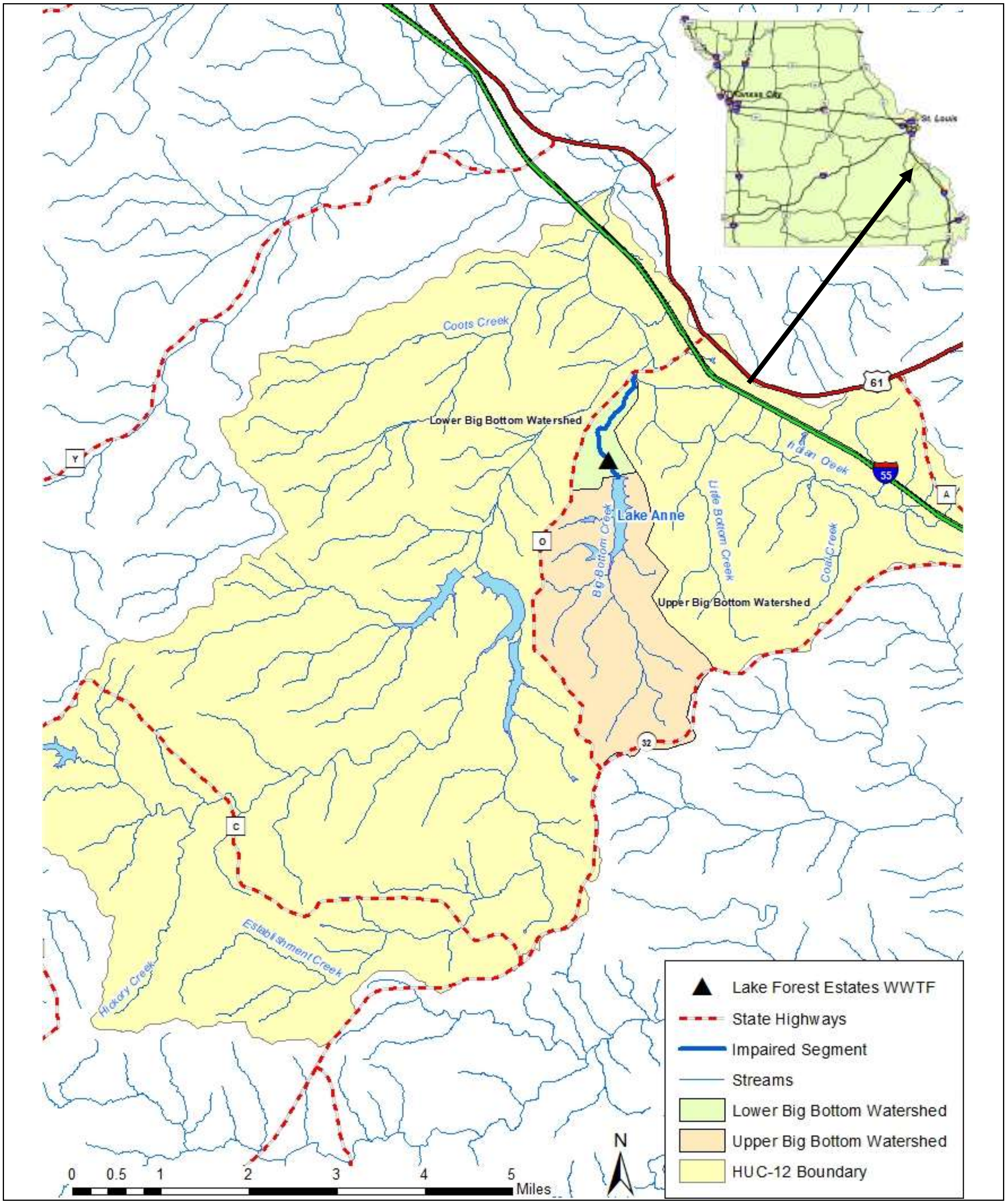

Figure 1. Location of the Big Bottom Creek Watershed within 12-Digit HUC 071401010907

3.1 Geology, Physiography and Soils

The Big Bottom Creek watershed is located within the Apple/Joachim ecological drainage unit (EDU). Ecological drainage units are groups of watersheds that have similar biota, geography, and climate characteristics (USGS 2009).The Apple/Joachim EDU lies in east-central Missouri and west-central Illinois, and includes all of the smaller direct tributaries to the Mississippi River between the outlets of the Missouri and Ohio Rivers. The Apple/Joachim EDU is entirely within the Ozark Highlands, but represents the northeastern boundary of this region. The EDU has a hydrologically diverse landscape with an equal mixture of surface water and spring-flow dominated streams (MoRAP 2005).

The Big Bottom Creek watershed is also located in the Eastern Ozark Border area of the Ozark Highlands Level IV ecoregion. The Eastern Ozark Border ecoregion is a transitional area between the Ozark Highlands and the Interior River Valleys and Hills ecoregion to the east. The area is characterized by moderately dissected hills and sheer bluffs. Soils can be rocky and thin on steep slopes. Native vegetation is a mix of oak forest, savanna, glades, and prairies, with more areas of cropland than adjoining Ozark regions (Chapman et al. 2002).

As presented in Table 1, soils in the lower Big Bottom Creek subwatershed consist of silt loam, cobbly silt loam, and rubbly rock outcrops (NRCS 2017). Although soils in the watershed are varied, they can be categorized based on similar runoff potentials into hydrologic soil groups. A hydrologic soil group indicates the rate at which water enters the soil profile under conditions of a bare, thoroughly wetted soil surface, which in turn may affect the potential amount of water entering the stream as runoff (NRCS 2009). Group A represents soils with the highest rate of infiltration and the lowest runoff potential. Group D soils have the lowest rate of infiltration and the highest potential for runoff. Group C soils have a low-moderate rate of infiltration and a moderate-high potential for runoff. Table 2 provides a summary of the hydrologic soils groups in the Big Bottom Creek watershed and Figure 2 shows their distribution. There are no Group A or B soils in the Big Bottom Creek watershed.

Table 1. Soil types in and adjacent to Big Bottom Creek (NRCS 2017)

Soil Type	Description	Characteristics	Hydrologic Soil Group	% of Watershed
Streambed				
Bloomsdale silt loam	1-3% slopes, frequently flooded	Well drained soils on Gravelly/Loamy Upland Drainageway Forest	C	24.8%
Adjacent Slopes				
Gasconade-Rock outcrop complex	15-50% slopes, rubbly	Somewhat excessively drained soils on Shallow Limestone/Dolomite Upland Glade/Woodland	D	32.7%
Goss very cobbly silt loam	15-50% slopes, extremely stony	Well drained soils on Chert Protected Backslope Forest	D	25.5%
Wrengart silt loam	8-15% slopes, eroded	Moderately well drained soils on Loamy Upland Woodland	C	16.1%

Table 2. Summary of Hydrologic Soil Groups in the Lower Big Bottom Creek Watershed (NRCS 2009)

Hydrologic Soil Group	Square Miles	Acres	Area (%)
C	0.202	129	41%
D	0.286	183	58%
Not Rated (Open Water)	0.005	3.2	1%
Total	0.493	315.2	100%

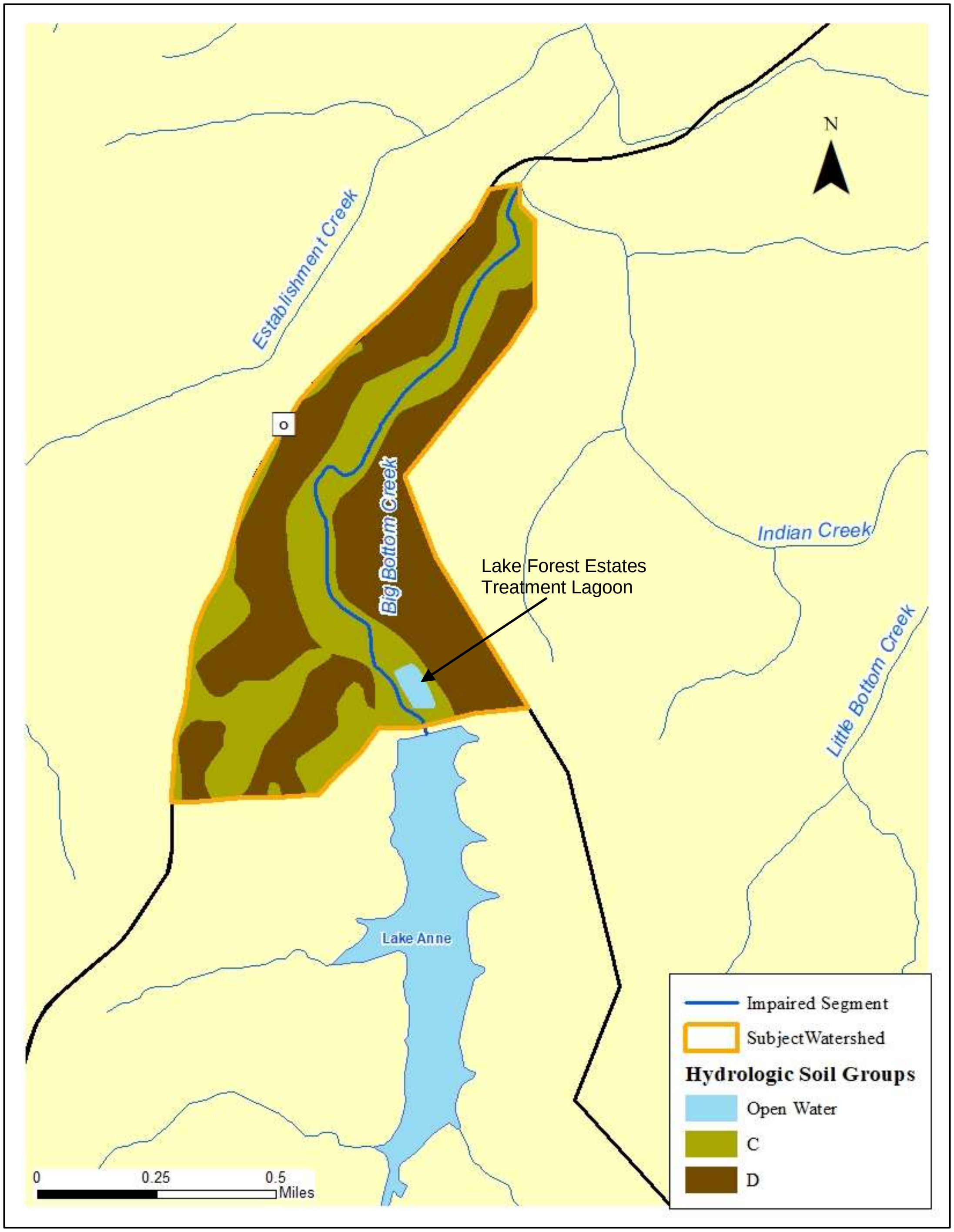

Figure 2. Hydrologic Soil Groups in the Lower Big Bottom Creek Watershed

3.2 Climate

Climate normals are 30-year averages of climatological variables, including temperature and precipitation, produced by the National Centers for Environmental Information every 10 years (NOAA 2010). The monthly precipitation and temperature normals calculated using daily weather data from the Prairie Du Rocher station (Station No. 116973) are representative of the climatic conditions in the watershed. Of the various climatic factors, precipitation is especially important as it is related to stream flow and runoff events that can influence the transport of pollutants from nonpoint sources into streams. This TMDL is based on data collected on July 7, 2009. Table 3 and figures 3 and 4 compare 2009 temperature and precipitation data in nearby Farmington, MO with the 30-year climate normal rainfall and temperature data observed at Station 116973 in Prairie Du Rocher. The U.S. Drought Monitor (University of Nebraska 2019) determined that the Cahokia-Joachim 8-digit HUC was not in drought in 2009.

Table 3. Comparison of Climate Normals and 2009 Data (#116973) (NOAA 2010)

	Precipitation (inches)		**Avg. Max. Temp. (ºF)**		**Avg. Min. Temp. (ºF)**	
Month	**Normal**	**2009**	**Normal**	**2009**	**Normal**	**2009**
January	2.32	2.38	41	39.1	22	18.3
February	2.76	1.84	46	48.4	26	27.6
March	3.50	2.70	57	59.5	37	35.0
April	4.45	6.30	67	63.9	44	44.2
May	5.08	7.28	74	75.0	53	53.0
June	3.70	2.70	83	84.3	62	65.1
July	3.94	6.43	87	81.5	66	61.8
August	3.94	1.51	87	83.6	64	61.0
September	3.46	2.80	79	77.6	55	58.2
October	3.23	11.09	68	61.8	44	43.1
November	4.69	2.68	56	62.9	35	40.7
December	3.54	3.86	43	42.3	25	24.4
	Total		**Average**		**Average**	
	44.6	51.6	65.7	65.0	44.4	44.4

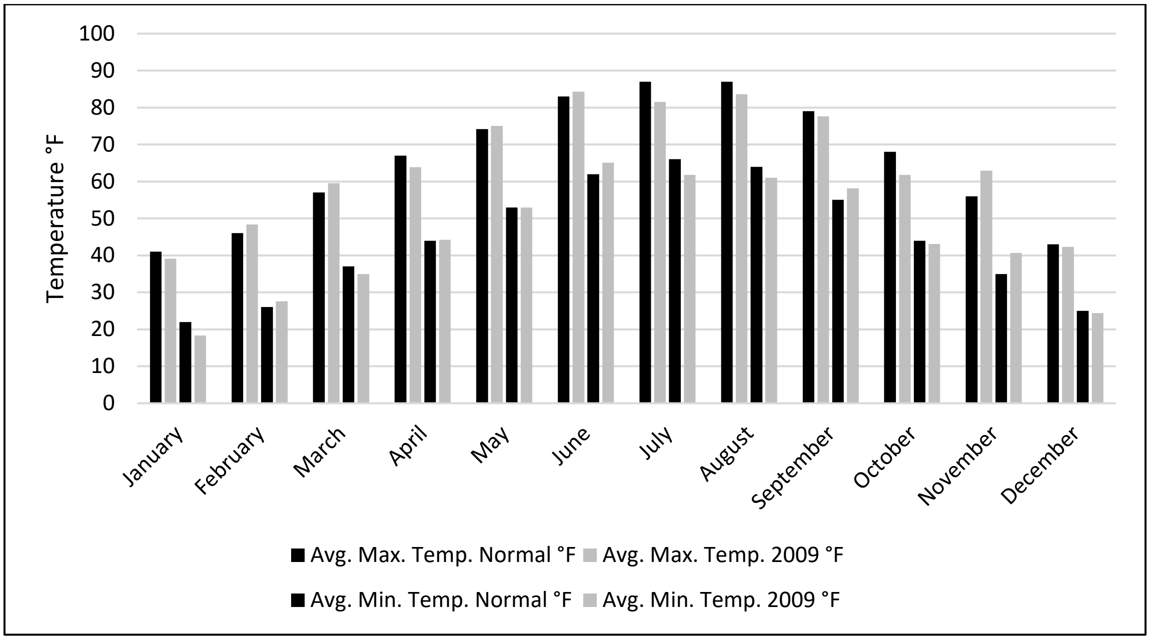

Figure 3. Comparison of Climate Normal and 2009 Monthly Average Monthly Minimum and Maximum Temperatures

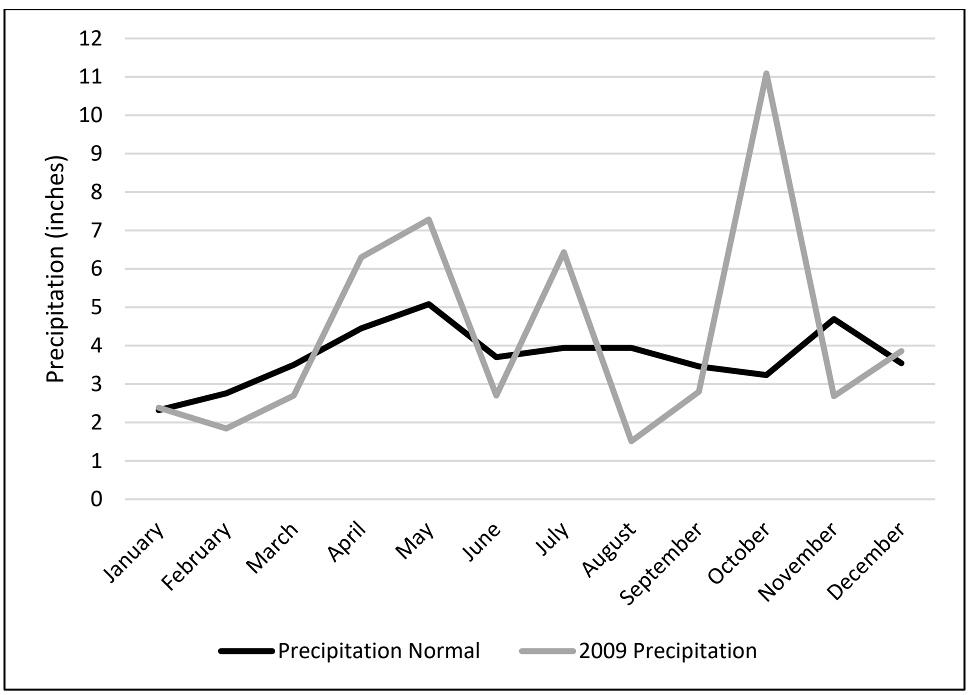

Figure 4. Comparison of Climate Normal and 2009 Average Monthly Precipitation

3.3 Population

Aerial imagery shows two dwellings in the 315-acre lower Big Bottom Creek watershed. The lower Big Bottom watershed is in an unincorporated area with no defined municipal or census defined urban areas.

In 2013, EPA completed a separate population analysis based on 12-digit HUC subwatersheds for purposes unrelated to this TMDL. They used demographic and census block data, and a web-based tool called EJSCREEN to determine areas of Missouri having potential Environmental Justice concerns. EPA defines Environmental Justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Environmental Justice communities may qualify for financial and strategic assistance for addressing environmental and public health issues. Data from 2013 do not include the Headwaters Establishment Creek 12-digit HUC indicating that there are no Environmental Justice concerns in this watershed.

3.4 Land Cover

A land cover analysis was completed using the 2011 National Land Cover Database published by the U.S. Geological Survey (USGS) (Homer et al. 2015). Land cover calculations are summarized in Table 4. Due to the presence of Lake Anne, only land areas below the dam directly contribute overland flow to the impaired stream and are considered in this TMDL report. The lower Big Bottom Creek watershed is primarily forested, but there are hay and pasture lands adjacent to the impaired segment of Big Bottom Creek. Forested lands inhibit nutrient transport via overland flow, but areas of hay and pasture lands coupled with the predominance of soils with high runoff potential (Table 2) increase the likelihood of sediment and nutrient transport into the stream from nonpoint sources. Figure 5 depicts the distribution of the land coverage throughout the watershed.

Table 4. Land Cover in the Lower Big Bottom Creek Watershed

Land Cover	Square Miles	Acres	Percent
Developed, Open Space	0.012	7.8	2.43%
Hay and Pasture	0.102	65	20.69%
Forest	0.358	229	72.62%
Shrub and Herbaceous	0.019	12	3.85%
Wetlands	0.002	1.4	0.41%
Total	0.493	315.2	100%

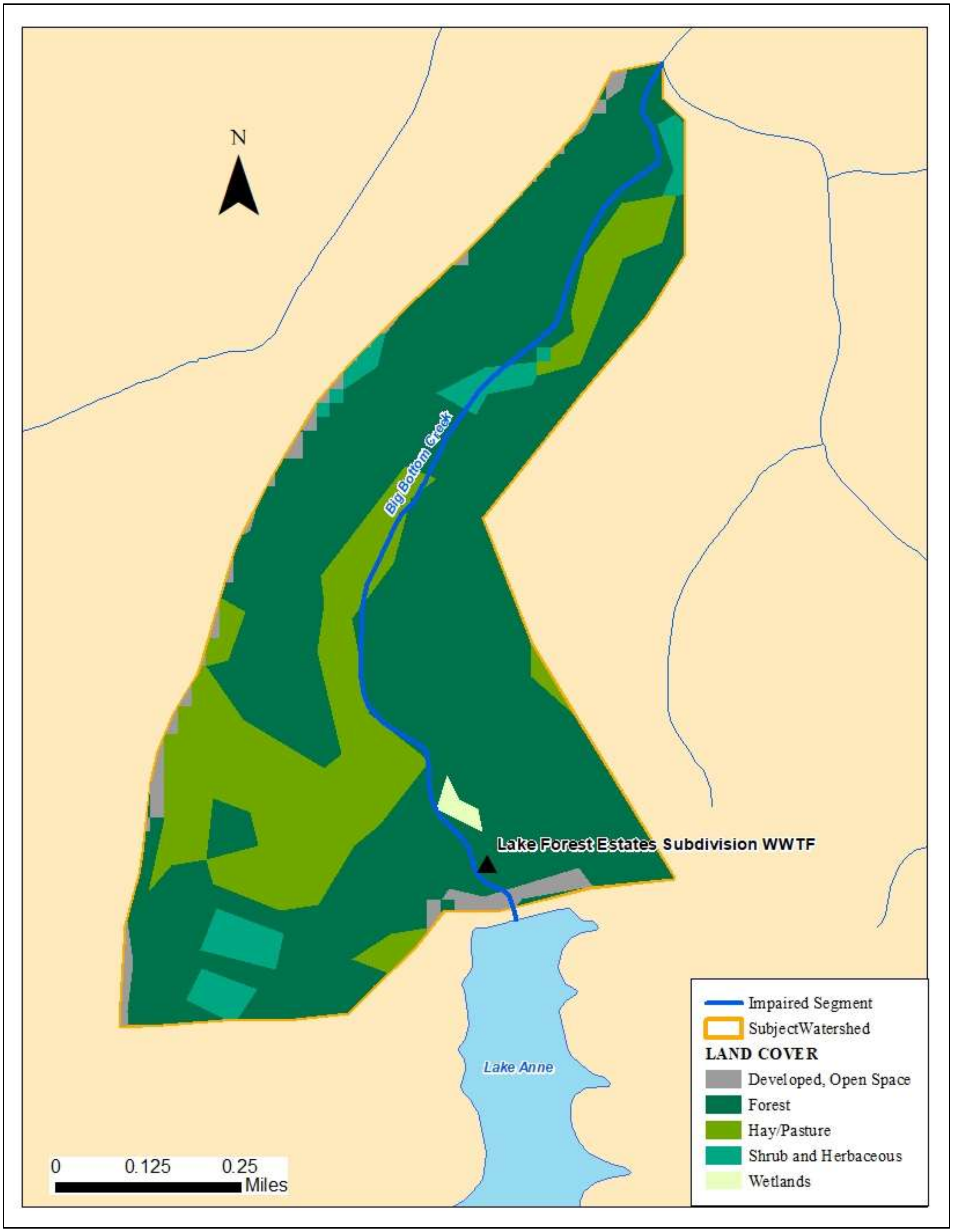

Figure 5. Land Cover in the Lower Big Bottom Creek Watershed

4. Applicable Water Quality Standards

The purpose of developing a TMDL is to identify the maximum pollutant loading that a water body can assimilate and still attain and maintain water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards consist of three major components: designated uses, water quality criteria, and an antidegradation policy.

Per federal regulations at 40 CFR 131.10, the designated uses and criteria to protect those uses assigned to a water body shall provide for the attainment and maintenance of the water quality standards of downstream waters. The components of Missouri's Water Quality Standards discussed in this section meet these requirements and are approved by the EPA. It is not the purview of a TMDL to revise existing water quality standards. In the event that future water quality monitoring demonstrates that water quality standards are not protective of downstream uses, the Clean Water Act provides means to address the situation. Such means are described in EPA's Water Quality Standards Handbook.[5]

4.1 Designated Uses

Designated uses are the uses for a water body defined in the Missouri's Water Quality Standards at 10 CSR 20-7.031(1)(C) and assigned per 10 CSR 20-7.031(2) and Table H. These uses must be maintained in accordance with the federal Clean Water Act. The impaired segment of Big Bottom Creek has been assigned the following designated uses as described at 10 CSR 20-7.031(2)(E):

- Irrigation;
- Livestock and wildlife protection;
- Human health protection;
- Warm water habitat (aquatic life); and
- Secondary contact recreation.[6]

Water body 1746 of Big Bottom Creek is impaired due to nonattainment of the warm water habitat aquatic life use.

4.2 Water Quality Criteria

Water quality criteria are limits on certain chemicals or conditions in a water body to protect particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements. Missouri 10 CSR 20-7.031(4) and (5) establish General Criteria applicable to all waters of the state at all times and Specific Criteria applicable to waters contained in 10 CSR 20-7.031 Tables G (Lakes) and H (Streams). Available data and field observations note water quality violations of general criteria associated with sediment loading as well as violations of the specific criterion for minimum dissolved oxygen and maximum ammonia nitrogen concentrations in warm water habitats.

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[5] https://www.epa.gov/wqs-tech/water-quality-standards-handbook

[6] Big Bottom Creek was not assigned a whole body contact recreational use in Missouri's 2005 water quality standards. A 2007 Use Attainability Analysis study confirmed that secondary contact recreation is the highest attainable recreational use in Big Bottom Creek. EPA approved the designation of the secondary contact recreational use for this stream on August 16, 2011.

Excessive sediment deposition, either organic or inorganic, that results in bottom deposits that harm aquatic life or otherwise prevent the full maintenance of beneficial uses are violations of the general criteria specified at 10 CSR 20-7.031(4)(A) and (C). For streams designated for the protection of aquatic life associated with the warm water habitat use, Table A1 of 10 CSR 20-7.031 specifies a minimum criterion of 5.0 mg/L of dissolved oxygen. Acute and chronic water quality criteria for total ammonia nitrogen (as NH_4-N) are based on pH and temperature as outlined in Tables B1 and B2 of 10 CSR 20-7.031.

The ultimate endpoint for this revised TMDL will be to meet Missouri Water Quality Standards through attainment of the minimum dissolved oxygen criterion of 5.0 mg/L, attainment of acute and chronic water quality criteria for total ammonia nitrogen, and attainment of general criteria associated with waters free from excessive sedimentation. Compliance with these criteria will be determined in accordance with Department assessment procedures for Clean Water Act sections 305(b) and 303(d) reporting.

4.3 Antidegradation Policy

Missouri's Water Quality Standards include the EPA "three-tiered" approach to antidegradation, and may be found at 10 CSR 20-7.031(3).

Tier 1 – Protects public health, existing instream water uses, and a level of water quality necessary to maintain and protect existing uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economic and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges, and waters of exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near, or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goal for Big Bottom Creek is to restore water quality to levels that meet the water quality standards.

5. Defining the Problem

The segment of Big Bottom Creek downstream of Lake Anne was placed on the Missouri 2002 303(d) List based on visual inspections below the Lake Forest Estates Subdivision Wastewater Treatment Facility during summer low flow conditions in 1995 and 2001. These inspections reported sludge deposits, green water, thick growths of prostrate algae, some filamentous algae, and

a scarcity of aquatic life. Almost all of the life forms that were present during these surveys are known to have a high tolerance for pollution. These conditions are characteristic of streams suffering from impacts by wastewater treatment facilities. Upgrades to the Lake Forest Estates Subdivision Wastewater Treatment Facility were completed in November 2004. Monitoring was conducted during low flows in 2005 through 2009 to determine if the facility upgrades had resolved the water quality violations. As presented in Figure 6, water quality data collected below the Lake Forest Estates Subdivision Wastewater Treatment Facility (Sample Point 1) during low flows in 2004-2009 indicate dissolved oxygen concentrations below 5.0 mg/L in 14 of 22 samples, including the years following the facility upgrade. All of the monitoring data found that water from the lake was not contributing to the impairments. Water only flows over the lake spillway during high flow periods. There is no flow in Big Bottom Creek below the dam upstream of the facility during low flow periods. During the 2009 monitoring events, it was noted that Big Bottom Creek was dry at its confluence with Indian Creek, but was flowing for some distance downstream of the Lake Forest Estates Subdivision Wastewater Treatment Facility. This indicates that during critical low flow conditions, effluent from the facility constitutes the entire flow in Big Bottom Creek from the facility to Indian Creek.

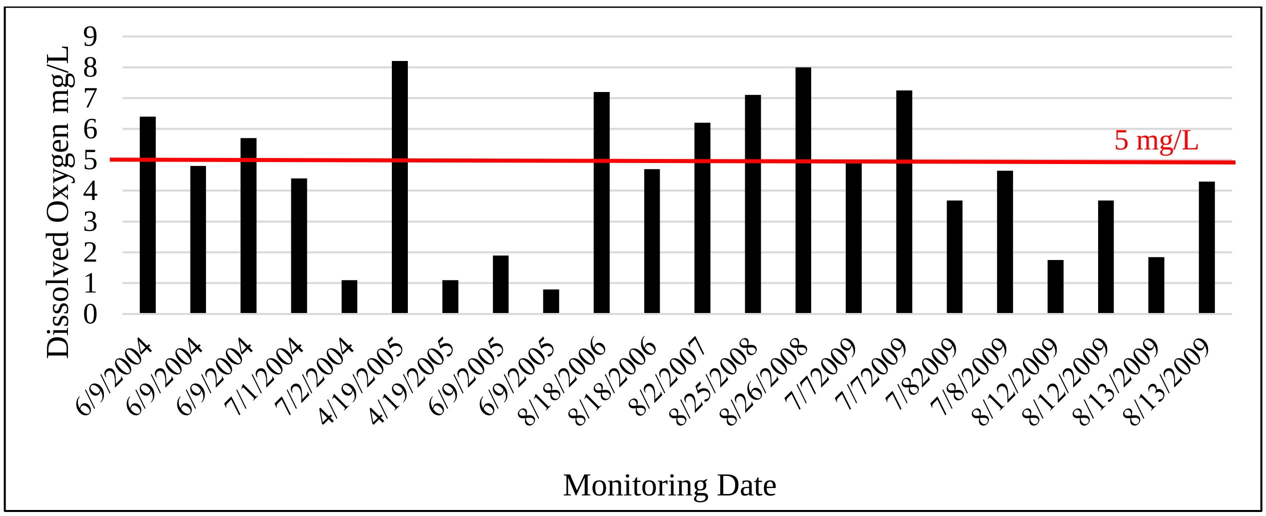

Figure 6. Dissolved oxygen concentrations immediately below the Lake Forest Estates Subdivision Wastewater Treatment Facility

Low dissolved oxygen is not a pollutant and cannot be allocated in a TMDL. However, biochemical oxygen demand is measurable and representative of both the quantity of oxygen demanding substances in effluent and the concentration of dissolved oxygen in the receiving stream. There is no numeric criterion in the Missouri Water Quality Standards for biochemical oxygen demand. However, Missouri Water Quality Standards do establish a minimum criterion of 5.0 mg/L for dissolved oxygen. Since dissolved oxygen cannot be allocated, but does have a numeric criterion, dissolved oxygen concentrations are linked to biochemical oxygen demand.

In-stream dissolved oxygen and biochemical oxygen demand are affected by several factors including water temperature, the amount of decaying matter (i.e., organic sediment containing nutrients) in the stream, nutrient transport into streams from overland runoff, turbulence at the air-water interface, and the amount of photosynthesis occurring in plants within the stream. Nutrients (i.e., nitrogen and phosphorus) enter streams from wastewater effluent as well as

agricultural and urban runoff. Decaying matter can also accumulate on the bottom of a stream and cause sediment oxygen demand. Sediment oxygen demand is a combination of all of the oxygen-consuming processes that occur at or just below the sediment-water interface. Most of the sediment oxygen demand at the surface of the sediment is due to the biological decomposition of organic material and the bacterially facilitated nitrification of ammonia nitrogen.

Excessive loads of decomposable organic matter from sewage effluent is likely the main contributor to low dissolved oxygen in Big Bottom Creek during critical low flows when effluent is most, if not all, of the stream flow.

6. Source Inventory and Assessment

A source inventory and assessment was conducted in order to determine whether other sources besides the Lake Forest Estates Subdivision Wastewater Treatment Facility may be contributing to the impairment of Big Bottom Creek. Potential sources of pollutant loading are categorized and quantified to the extent that information is available. These sources are categorized as being either point (regulated) or nonpoint (unregulated).

6.1 Point Sources

Point sources are defined under Section 502(14) of the federal Clean Water Act and are typically regulated through the Missouri State Operating Permit program.[7] Point sources include any discernible, confined, and discrete conveyance, such as a pipe, ditch, channel, tunnel, or conduit, by which pollutants are transported to a water body. Under this definition, permitted point sources include permitted municipal and domestic wastewater dischargers, site-specific permitted industrial and non-domestic wastewater dischargers, concentrated animal feeding operations (CAFOs), municipal separate storm sewer systems (MS4s), and general wastewater and stormwater permitted entities. In addition to these permitted sources, illicit straight pipe discharges, which are illegal and therefore unpermitted, are also point sources.

6.1.1 Municipal and Domestic Wastewater Discharge Permits

Dischargers of domestic wastewater include both publicly owned municipal wastewater treatment facilities and private non-municipal treatment facilities. Domestic wastewater is primarily household waste, including graywater and sewage. Untreated or inadequately treated discharges of domestic wastewater can be significant sources of biochemical oxygen demand, nitrogen, and phosphorus to receiving waters. Influences of pollutant loading from domestic dischargers are typically most evident at low-flow conditions when stormwater influences are lower or nonexistent.

The only domestic wastewater facility in the lower Big Bottom Creek watershed is the private Lake Forest Estates Subdivision Wastewater Treatment Facility (Table 5). Due to past field observations, proportion of contributing flow, and the location of known water quality excursions, this facility is considered to be the primary cause of water quality impairment in Big Bottom Creek.

[7] The Missouri State Operating system is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES) program. The NPDES program requires all point sources that discharge pollutants to waters of the United States to obtain a permit. Issued and proposed operating permits are available online at dnr.mo.gov/env/wpp/permits/index.html.

Table 5. Point Sources in the Lower Big Bottom Creek Watershed

Facility	Permit No.	Design Flow (gallons/day)	Actual Flow (gallons/day)	Expires
Lake Forest Estates Subdivision WWTF	MO-0035742	118,300	99,300	1/31/2021

In addition to the direct discharges from domestic wastewater treatment facilities, potential pollutant contributions may also occur from overflows occurring from the adjoining sanitary sewer system. A sanitary sewer system is a wastewater collection system designed to convey domestic, commercial, and industrial wastewater to the treatment facility. This system can include limited amounts of inflow and infiltration from groundwater and stormwater, but it is not designed to collect large amounts of runoff from precipitation events. Untreated or partially treated discharge from a sanitary sewer system is referred to as a sanitary sewer overflow. Sanitary sewer overflows can be caused by a variety of factors including blockages, line breaks, sewer defects, power failures, and vandalism. Sanitary sewer overflows can occur during either dry or wet weather and at any point in the collection system including overflows from manholes or backups into private residences. Because the Lake Forest Estates Subdivision Wastewater Treatment Facility utilizes a lagoon for water treatment, high precipitation can result in overflow from the lagoon and insufficient residence time for the treatment of wastewater. However, such overflows are not expected to occur during critical low-flow conditions. These types of discharges are unauthorized by the federal Clean Water Act and should remain rare and be eliminated to the maximum extent possible.

6.1.2 Site-Specific Industrial and Non-Domestic Wastewater Permits

Industrial and non-domestic facilities discharge wastewater resulting from non-sewage generating activities. There are no site-specific industrial or non-domestic wastewater permits in the lower Big Bottom Creek watershed.

6.1.3 CAFO Permits

Concentrated animal feeding operations are animal feeding operations that confine and feed or maintain more than 1,000 animal units for 45 days or more during any 12-month period. Facilities with fewer animal units may be permitted as CAFOs if discharges occur or other water quality issues are discovered per 10 CSR 20-6.300. In Missouri, these types of facilities are permitted with either a site-specific permit or one of two available CAFO general permits. There are no CAFOs in the Big Bottom Creek watershed.

6.1.4 Municipal Separate Storm Sewer System (MS4) Permits

A municipal separate storm sewer system (MS4) is a stormwater conveyance system owned by a public entity that is not a combined sewer or part of a sewage treatment plant. Federal regulations issued in 1990 require discharges from such systems to be regulated by permits if a municipality or county population is 100,000 or more. In 1999, new federal regulations required permits for discharges from small MS4s that are located within a U.S. Census Bureau defined urban area or have otherwise been designated as needing a permit by the permitting authority. There are no permitted entities of this type in the lower Big Bottom Creek watershed.

6.1.5 General Wastewater and Non-MS4 Stormwater Permits

General and stormwater permits are issued based on the type of activity occurring and are intended to be flexible enough to allow for ease and speed of issuance, while providing the required protection of water quality. General and stormwater permits are issued for activities similar enough to be covered by a single set of requirements and are designated with permit numbers beginning with “MO-G” or “MO-R,” respectively. There are no active general or stormwater permits in the lower Big Bottom Creek watershed.

6.1.6 Illicit Straight Pipe Discharges

Illicit straight pipe discharges of domestic wastewater are also potential point sources of nutrients and oxygen consuming substances. These types of sewage discharges bypass treatment systems, such as a septic tank or a sanitary sewer, and instead discharge directly to a stream or an adjacent land area (Brown and Pitt 2004). Illicit straight pipe discharges are illegal and not authorized under the federal Clean Water Act. At present, there are no data about the presence or number of illicit straight pipe discharges in the lower Big Bottom Creek watershed. For this reason, it is unknown to what significance straight pipe discharges contribute pollutant loads to Big Bottom Creek. However, due to the lack of residential properties and small population present in this watershed, illicit straight pipe discharges are not expected to be a major contributor to the water quality impairments of Big Bottom Creek. Because these types of discharges are illegal, any identified illicit straight pipe discharges must be eliminated.

6.2 Nonpoint Sources

Nonpoint source pollution refers to pollution coming from diffuse, non-permitted sources that typically cannot be identified as entering a water body at a single location and include all other categories of pollution not classified as being from a point source. Nonpoint sources are exempt from Department permit regulations per state rules at 10 CSR 20-6.010(1)(B)1. These sources involve stormwater runoff over land and are typically minor or negligible under low-flow conditions. Runoff from agricultural areas and non-MS4 permitted urban areas, onsite wastewater treatment systems, and areas with poor riparian corridor conditions are typical sources of nonpoint pollutants that contribute to water quality impairments.

6.2.1 Agricultural Runoff

Stormwater runoff and soil erosion from lands used for agricultural purposes (hay and pasture, and cropland) are sources of sediment and nutrient loading. Fertilizer is applied to agricultural lands as chemical forms of nitrogen and phosphorus and as animal manure. Application rates and timing vary by site depending upon a number of factors, including manure quality and soil fertility. Livestock that are not excluded from streams may deposit manure directly into waterways. Operations using nutrient management plans to guide fertilizer applications and employ best management practices to reduce soil erosion and exclude animals from streams will contribute smaller nutrient and sediment loads than those that do not.

As noted in Section 3.4, the lower Big Bottom Creek watershed is primarily forested with no cropland identified in the watershed. Riparian areas in the watershed are also primarily forested and inhibit nutrient and sediment transport via overland flow. Therefore, nonpoint source loading from agricultural runoff is not expected to cause or contribute to the water quality impairments of Big Bottom Creek. Additionally, pollutant loading from agricultural areas would be negligible during

the critical low-flow condition when precipitation is minimal and low dissolved oxygen conditions are common.

6.2.2 Unregulated Urban Runoff

Urban stormwater that is not regulated through MS4 permits is considered a nonpoint source. Due to a lack of impervious urban land cover, there are no sources of unregulated urban runoff in the lower Big Bottom Creek watershed.

6.2.3 Onsite Wastewater Treatment Systems

Approximately 25 percent of homes in Missouri utilize onsite wastewater treatment systems, particularly in rural areas where public sewer systems may not be available (DHSS 2018). Onsite wastewater treatment systems treat domestic wastewater and disperse it to the property from where it is generated (i.e., a home septic system). When properly designed and maintained, such systems perform well and should not serve as a source of contamination to surface waters. However, onsite wastewater treatment systems can fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration), there can be adverse effects to surface water quality (Horsley and Witten 1996). Failing onsite wastewater treatment systems can contribute nutrient loads and oxygen consuming substances to nearby streams under wet or dry weather conditions through surface runoff and groundwater flows. Onsite wastewater treatment systems may contribute pollutants to water bodies directly or as component of stormwater runoff.

Based on observations using aerial imagery, only two dwellings are present in the lower Big Bottom Creek watershed. The homes are greater than 580 feet from Big Bottom Creek and any associated septic systems likely do not contribute significant pollutant loading to the impaired water body.

6.2.4 Riparian Corridor Conditions

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal, and assimilation of pollutants in runoff. Therefore, a stream with good riparian cover is often better able to mitigate the impacts of high pollutant loads than a stream with poor or no riparian cover. Shade provided by riparian corridors is also important because helps to keep water cooler and reduce temperature variation especially during the critical low flows of July and August.

Table 6 presents land cover calculations for the area within 100 feet of the impaired segment of Big Bottom Creek. Note that 19.9 percent of the riparian corridor is located in hay and pasture lands, which likely contribute to sediment and nutrient loading during precipitation events due to erosion and stormwater runoff into Big Bottom Creek.

Table 6. Land Cover within 100 feet (30 meters) of the Impaired Segment and Tributaries

Land Cover	Area (acres^2)	Percent
Developed, Open Space	0.74	2.2%
Hay and Pasture	6.84	19.9%
Forest	24.3	70.6%
Shrub and Herbaceous	2.22	6.5%
Wetlands	0.31	0.9%
Total	34.41	100.0%

7. Numeric TMDL Targets and Modeling Approach

The pollutant targets in this revised TMDL have been established such that dissolved oxygen concentrations in Big Bottom Creek will meet the minimum criterion of 5.0 mg/L, ammonia nitrogen will meet the chronic criterion, and organic sediment loads will be reduced so that general (narrative) criteria are met. Attainment of these criteria are protective of the warm water habitat designated use during critical low flow conditions when effluent flow dominates. Since dissolved oxygen is not a pollutant and cannot be allocated in a TMDL, numeric targets selected to address the dissolved oxygen impairment are biochemical oxygen demand, total suspended solids, ammonia nitrogen, total nitrogen, and total phosphorus. Applicability and support for the selected targets is provided using a QUAL2K model.

7.1 Total Nitrogen and Total Phosphorus

Organic sediment discharged into streams contains nitrogen and phosphorus (nutrients/organic material) and results in the depletion of dissolved oxygen concentrations as oxygen is used to facilitate the biochemical processes of decomposition. In the presence of organic sediment and nutrients, dissolved oxygen in the stream is consumed faster than it can be replenished through atmospheric oxygen exchange and aquatic organism photosynthesis. This results in low dissolved oxygen until the organic matter has decomposed enough that dissolved oxygen replenishment exceeds dissolved oxygen consumption.

7.2 Biochemical Oxygen Demand

Biochemical oxygen demand is representative of both the quantity of organic sediment in effluent and the concentration of dissolved oxygen in the receiving stream. Biochemical oxygen demand is composed of carbonaceous biochemical oxygen demand (CBOD) (i.e., the amount of oxygen needed for the microbial utilization of carbon compounds) and nitrogenous biochemical oxygen demand (NBOD) (i.e., the amount of oxygen needed for the microbial oxidation of certain nitrogen compounds). Nitrogenous biochemical oxygen demand is estimated directly from Total Kjeldahl Nitrogen (TKN), which is ammonia nitrogen (NH_4-N) plus organic nitrogen.

7.3 Ammonia as Nitrogen (NH_4-N)

Ammonia nitrogen can influence water quality in natural systems in two ways. The nitrification process in which ammonia nitrogen is reduced to nitrate (NO_3) consumes an estimated 4.2-4.6 grams of oxygen as O_2 per gram of ammonia as NH_4 (Cox 2003). High ammonia nitrogen concentrations in wastewater effluent exert a high oxygen demand (NBOD) that can contribute to low dissolved oxygen in receiving streams. In addition to depleting oxygen, ammonia can be toxic to aquatic life and must not exceed the concentrations found in Tables B1 and B2 of Missouri's Water Quality Standards. Water quality targets for ammonia nitrogen must be protective of both possible pathways.

7.4 Total Suspended Solids

Total suspended solids are solids that are suspended (i.e., floating) in stream water or wastewater effluent that can be removed by filtration and are comprised of both inorganic and organic substances. Because phosphorus can adhere to soil carried in runoff and organic sediment is a component of total suspended solids, reductions in total suspended solids are expected to result in additional nutrient and organic loading reductions that impact overall instream dissolved oxygen

concentrations. The sediment target for this TMDL is the same as that derived for the original 2010 TMDL. In this approach, the target pollutant loading is based on the 25th percentile concentration of all total suspended solids data available (USGS, non-filterable residue) within the EDU in which Big Bottom Creek is located. For Big Bottom Creek, the calculated total suspended solids target is 10 mg/L.

7.5 QUAL2K Modeling

QUAL2K is a steady state model based on the Streeter-Phelps equation that estimates the effects of point source biochemical oxygen demand from sewage effluent on receiving stream dissolved oxygen concentrations. QUAL2K simulates the link between dissolved oxygen and biochemical oxygen demand. The QUAL2K model calculates biochemical oxygen demand by using CBOD, organic nitrogen, and ammonia nitrogen data from the wastewater treatment facility's discharge monitoring report and produces estimates of in-stream dissolved oxygen concentrations.

Two QUAL2K models, a calibration model and a critical condition model, were developed to determine the effects of effluent from the Lake Forest Estates Subdivision Wastewater Treatment Facility on dissolved oxygen concentrations in Big Bottom Creek. Because Big Bottom Creek above the facility is dry during low-flow conditions, the inputs used for the headwater condition in the 2019 Revised QUAL2K models were estimated. The headwater condition uses a combination of water quality data recorded at Sample Point 1 (Figure 7) on July 8, 2009 and effluent data recorded in the July 31, 2009, discharge monitoring report for the Lake Forest Estates Subdivision Wastewater Treatment Facility. The inputs were chosen to provide the most conservative assumptions, as well as to align the best-fit of the QUAL2K model to the observed data. The rates and formulas assigned to calibrate the QUAL2K model were retained for the wasteload allocation model. Because the Lake Forest Estates Subdivision Wastewater Treatment Facility constitutes the entire flow in Big Bottom Creek below the Lake Anne spillway during dry months, the model headwater and point source inputs are the same. In order to improve and restore the condition of the impaired segment, biochemical oxygen demand, total suspended solids, and ammonia nitrogen in facility effluent must be reduced and maintained at lower concentrations.

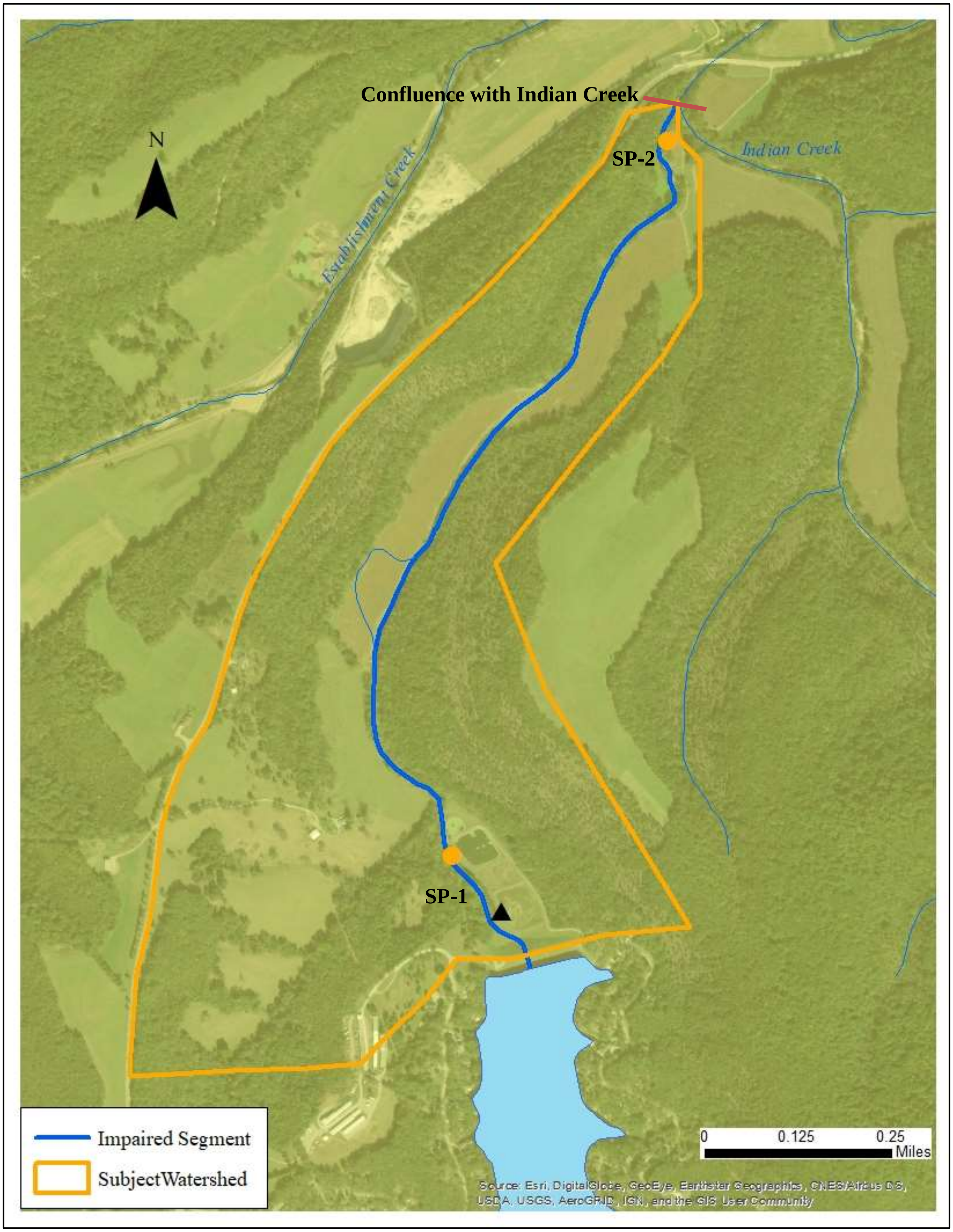

Figure 7. Downstream Monitoring Locations

8. Calculating Loading Capacity

A TMDL calculates the loading capacity of a water body and allocates that load among the various pollutant sources in the watershed. The loading capacity is the maximum pollutant load that a water body can assimilate and still meet water quality standards. The TMDL is equal to the sum of the wasteload allocations, load allocations, and the margin of safety:

$$\text{TMDL} = \text{LC} = \Sigma\text{WLA} + \Sigma\text{LA} + \text{MOS}$$

where LC is the loading capacity, ΣWLA is the sum of the wasteload allocations, ΣLA is the sum of the load allocations, and MOS is the margin of safety.

The following formula is used to convert pollutant concentrations to pounds/day:

(flow in ft^3/sec)(maximum allowable pollutant concentration in mg/L)(5.395*)= pounds/day
*5.395 is the constant used to convert units to pounds/day.

For this TMDL, the loading capacity is calculated at critical low flow conditions when in-stream conditions are most likely to result in violations of Missouri's dissolved oxygen criterion due to increased temperature, and limited dilution and flow. The loading capacity for the impaired segment of Big Bottom Creek is equal to the Lake Forest Estates Subdivision Wastewater Treatment Facility wasteload allocation. This is because there are no other significant point or nonpoint source contributors during critical low flow conditions. Under the critical condition, the Lake Forest Estates Subdivision Wastewater Treatment Facility is the predominant, if not the only, contributor to stream water quality. The loading capacity for the impaired segment of Big Bottom Creek during low flow conditions is presented in Table 7. Additional discussion regarding allocation of the loading capacity and margin of safety is provided in the following sections.

Table 7. Low Flow TMDL for Big Bottom Creek

Pollutant	Loading Capacity (lbs/day)	∑Wasteload Allocation (lbs/day)	∑Load Allocation (lbs/day)
BOD_5	4.96	4.96	0
TP	0.50	0.50	0
TN	4.96	4.96	0
NH_3-N	0.99	0.99	0
TSS	9.93	9.93	0

9. Wasteload Allocation (Allowable Point Source Load)

The wasteload allocation is the allowable amount of the loading capacity assigned to existing or future point sources. This section discusses the rationale and approach for assigning wasteload allocations to point sources in the lower Big Bottom Creek watershed as well as considerations given for future sources. Typically, point source permit limits for a given pollutant are the most stringent of either technology-based effluent limits or water quality-based effluent limits. Technology-based effluent limits are based upon the expected capability of a treatment method to reduce the pollutant to a certain concentration. Water quality-based effluent limits represent the most stringent concentration of a pollutant that a receiving stream can assimilate without violating applicable water quality standards at a specific location. Final effluent limits or other permit conditions must be consistent with the assumptions and requirements of TMDL wasteload

allocations per 40 CFR 122.44(d)(1)(vii)(B). Mixing zones and zones of initial dilution are not allowed in regulation for streams with 7Q10 low flows of less than 0.1 cubic feet per second [10 CSR 20-7.031(5)(A)4.B.(I)]. Therefore, in order to ensure attainment of applicable water quality standards in Big Bottom Creek, all water quality targets must be met at end of pipe. The wasteload allocations in this TMDL report do not authorize any facility to discharge pollutants at concentrations that exceed water quality standards.

9.1 Municipal and Domestic Wastewater Discharges

As noted in Section 6.1.1, the only permitted domestic wastewater discharge in the lower Big Bottom Creek watershed is the Lake Forest Estates Subdivision Wastewater Treatment Facility. The wasteload allocations for the Lake Forest Estates Subdivision Wastewater Treatment Facility are based on the facility's design flow and the water quality targets shown to attain the minimum dissolved oxygen criterion for the protection of warm water habitat (Table 8).

Table 8. Wasteload Allocations for Lake Forest Estates Subdivision WWTF

Effluent Parameter	Design Flow (GPD)	Existing Permit Limit[8]		WLA at Design Flow		Percent Reduction
		Concentration (mg/L)	Load (lbs/day)	Concentration (mg/L)	Load (lbs/day)	
BOD_5	118,300	Monthly Average BOD_5 = 30	30	5.0	4.96	83%
TP	118,300	No Existing Limit	N/A	0.5	0.50	N/A
TN	118,300	No Existing Limit	N/A	5.0	4.96	N/A
NH_3-N	118,300	Monthly Average = 1.9	1.9	1.0	0.99	47%
TSS	118,300	Monthly Average = 30	30	10.0	9.93	48%
DO*	118,300	No Existing Limit	N/A	6.0	N/A	N/A

* Note: For water quality standards to be attained at specified wasteload allocations, facility effluent should be maintained to no less than 6.0 mg/L dissolved oxygen.

For point source reductions to achieve the specified loading targets, upgrades to the Lake Forest Estates Subdivision Wastewater Treatment Facility, such as enhanced nutrient removal, may be necessary. Wasteload allocation targets may also be attained through a nutrient trading program, which should be conducted in accordance with the conditions and requirements specified in the Missouri Water Quality Trading Framework.[9] Water quality trading is a voluntary, market-based implementation tool that may be used in coordination with traditional regulatory programs, such as TMDLs, to maximize environmental outcomes and achieve water quality improvements (USEPA 2019).

[8] Limits based on those required in permit valid from February 1, 2016 to January 31, 2022

[9] The Missouri Water Quality Trading Framework is available online at dnr.mo.gov/env/wpp/cwc/docs/tab-10-wqtrading-framework.pdf and was approved by the Clean Water Commission on October 5, 2016. Future revisions to this document that are approved by the Clean Water Commission will supersede the version cited in this TMDL amendment.

9.2 Site-Specific Permitted Industrial and Non-Domestic Wastewater Facilities

There are no site-specific permitted industrial and non-domestic wastewater facilities in the lower watershed of Big Bottom Creek. Therefore, such sources are not assigned a portion of the calculated loading capacity.

9.3 CAFOs

There are no CAFOs in the lower Big Bottom Creek watershed, thus CAFOs are not assigned a portion of the calculated wasteload allocation.

9.4 MS4 Permits

There are no municipalities or urban areas in the lower Big Bottom Creek watershed that require MS4 systems or permits, thus regulated MS4s are not assigned a portion of the calculated wasteload allocation.

9.5 General Wastewater and Non-MS4 Stormwater Permits

The Department assumes that activities conducted in compliance with all specified general and stormwater permit conditions, including land application, monitoring, and discharge limitations, will not contribute significant pollutant loads to surface waters. It is expected that compliance with these types of permits will be protective of the applicable designated uses within the watershed. There are no general or non-MS4 stormwater permitted entities in the lower Big Bottom Creek watershed. Therefore, such sources are not assigned a portion of the calculated loading capacity.

9.6 Illicit Straight Pipe Discharges

Illicit straight pipe discharges are illegal and are not permitted under the federal Clean Water Act. For this reason, illicit straight pipe discharges are assigned a wasteload allocation of zero. Any existing sources of this type must be eliminated.

9.7 Considerations for Future Point Sources

For this TMDL, no specific portion of the loading capacity is allocated to a reserve capacity. However, the wasteload allocations presented in this TMDL report do not preclude the establishment of future point sources in the watershed. Any future point sources should be evaluated against the TMDL, the range of flows with which any additional loading will affect, and any additional requirements associated with antidegradation. Per federal regulations at 40 CFR 122.4(a), no permit may be issued when the conditions of the permit do not provide for compliance with the applicable requirements of the federal Clean Water Act, or regulations promulgated under the federal Clean Water Act. Additionally, 40 CFR 122.4(i) states no permit may be issued to a new source or new discharger if the discharge from its construction or operation will cause or contribute to violation of water quality standards. Facility types not currently existing in the watershed and not allocated a portion of the loading capacity may be permitted as no discharge facilities as long as permit conditions for land application or other controls maintain potential loading at *de minimis* concentrations. Future general (MO-G) and stormwater (MO-R) permitted activities that operate in full compliance with permit conditions are not expected to cause or contribute to water quality excursions and will not result in loading that exceeds the sum of the TMDL wasteload allocations.

10. Load Allocation (Nonpoint Source Load)

The load allocation is the amount of the pollutant load that is assigned to existing and future nonpoint sources, as well as natural background contributions (40 CFR 130.2(g)). Load allocations for this TMDL are calculated as the remainder of the loading capacity after allocations to the wasteload allocation (Table 7). Because the loading capacity was calculated based on the critical low-flow condition when nonpoint sources are not expected to contribute to the impairment, nonpoint sources are assigned a load allocation of zero at critical low flows.

11. Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems (CWA 303(d)(l)(C) and 40 C.F.R. 130.7(c)(l)). The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through two approaches:

- Explicit - Reserve a portion of the loading capacity as a separate term in the TMDL.
- Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

For this TMDL an implicit margin of safety was used. The margin of safety was incorporated into the development of this TMDL by making conservative assumptions in the analysis as follows:

- The 7Q10 low flow value was used for the headwater flow rate.
- Due to lack of flow above the Lake Forest Estates Subdivision Wastewater Treatment Facility, the effluent concentrations used for the point source inputs were also used for the headwater inputs.
- The QUAL2K calibration model overestimates biochemical oxygen demand, thus the critical condition model also overestimates biochemical oxygen demand. Despite this additional oxygen demand, the final targets still result in dissolved oxygen concentrations that meet the minimum 5.0 mg/L criterion.
- The QUAL2K estimates the oxygen demand for the nitrification of NH_4 to nitrate (NBOD) twice, because where the model asks for $CBOD_5$, total biochemical oxygen demand (CBOD + NBOD) from the facility's discharge monitoring report was entered in addition to ammonia nitrogen.

12. Seasonal Variation

Federal regulations at 40 CFR 130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. This TMDL considered seasonal variation by assuming that the Lake Forest Estates Subdivision Wastewater Treatment Facility accounts for the entire flow in Big Bottom Creek during critical low-flow conditions. Flow was not present above the facility during any summer monitoring, and Big Bottom Creek was dry for some distance upstream of Indian Creek during the August 2009 monitoring events. During the winter, water flows over the Lake Anne dam and additional dilution of effluent occurs. The water quality standards implicitly account for seasonal variation by establishing NH_4-N criteria based on pH and temperature such that the criteria are lower when water temperatures are higher. In addition, colder water (winter) holds more oxygen, but calculations of loading capacity are based on achieving the dissolved oxygen criterion

of 5.0 mg/L during summer low-flows conditions and during the warmest temperatures, which offers the maximum protection for the stream. Protection of the critical low-flow condition will ensure that the TMDL is protective of elevated flows during other seasons.

13. Monitoring Plans

The Department often schedules and carries out post-TMDL monitoring within a reasonable timeframe following completion of permit compliance schedules, facility upgrades, or the implementation of watershed best management practices. No upgrades to the Lake Forest Estates Subdivision Wastewater Treatment Facility have occurred since Big Bottom Creek was placed on the 2008 303(d) List. Therefore, no monitoring is scheduled at this time. The Department may examine quality-assured water quality data collected by other local, state, and federal entities in order to assess the effectiveness of TMDL implementation. In addition, certain quality-assured data collected by universities, municipalities, private companies, and volunteer groups may potentially be considered for monitoring water quality following TMDL implementation.

14. Reasonable Assurance

Section 303(d)(1)(C) of the federal Clean Water Act requires that TMDLs be established at a level necessary to implement applicable water quality standards. As part of the TMDL process, consideration must be given to the assurances that point and nonpoint source allocations will be achieved and water quality standards attained. Where TMDLs are developed for waters impaired by point sources only, reasonable assurance is provided through the National Pollutant Discharge Elimination System (NPDES) permitting program. State operating permits requiring effluent and instream monitoring be reported to the Department should provide reasonable assurance that instream water quality standards will be met. The Department regulates discharges from the Lake Forest Estates Subdivision Wastewater Treatment Facility through Missouri State Operating Permit MO-0035742.

Where a TMDL is developed for waters impaired by both point and nonpoint sources, point source wasteload allocations must be stringent enough so that in conjunction with the water body's other loadings (i.e., nonpoint sources) water quality standards are met. Reasonable assurance that nonpoint sources will meet their allocated amount is dependent upon the availability and implementation of nonpoint source pollutant reduction plans, controls, or best management practices within the watershed. If best management practices or other nonpoint source pollution controls allow for more stringent load allocations, then wasteload allocations can be less stringent. Thus, the TMDL process provides for nonpoint source control tradeoffs (40 CFR 130.2(i)). When a demonstration of nonpoint source reasonable assurance is developed for an impaired water body, additional pollutant allocations for point sources may be allowed provided water quality standards are still attained. If a demonstration of nonpoint source reasonable assurance does not exist, or it is determined that nonpoint source pollutant reduction plans, controls, or best management practices are not feasible, durable, or will not result in the required load reductions, then allocation of greater pollutant loading to point sources cannot occur. This TMDL does not include wasteload allocations that are less stringent than the water quality targets determined to attain water quality standards.

A variety of grants and loans may be available to assist watershed stakeholders with developing and implementing watershed based plans, controls, and practices to meet the required wasteload and load allocations in the TMDL and demonstrate reasonable assurance. Additionally, cost-share opportunities for implementation of agricultural best management practices are also available.

Information regarding potential funding sources, cost-share opportunities, and implementation actions addressing pollutant sources in the Big Bottom Creek watershed is provided in the supplemental TMDL Implementation Strategies document available online at dnr.mo.gov/env/wpp/tmdl/1746-big-bottom-ck-record.htm.

15. Public Participation

EPA regulations at 40 CFR 130.7 require that TMDLs be subject to public review. A 45-day public notice period was held for this revised TMDL from September 10 through October 25, 2019. No comments were received during the public notice period. Groups that directly received notice of the public comment period for this TMDL included, but were not limited to:

- Missouri Clean Water Commission;
- Missouri Water Protection Forum;
- Missouri Department of Conservation;
- County soil and water conservation district;
- County commission;
- Southeast Missouri Regional Planning Commission;
- University of Missouri Extension;
- Missouri Coalition for the Environment;
- Stream Teams United;
- Stream Team volunteers living in or near the watershed;
- Affected permitted entities; and
- Missouri state legislators representing areas within the watershed.

In addition to those groups contacted directly about the public notice, the Department posted this TMDL amendment and an implementation strategies document online at dnr.mo.gov/env/wpp/tmdl/1746-big-bottom-ck-record.htm.

The Department also maintains an email distribution list for notifying subscribers of significant TMDL updates or activities, including public notices and comment periods. Those interested in subscribing to TMDL updates can submit their email address using the online form available at public.govdelivery.com/accounts/MODNR/subscriber/new?topic_id=MODNR_177.

16. Administrative Record and Supporting Documentation

The Department has an administrative record on file for the Big Bottom Creek TMDL. The record contains any plans, studies, data, and calculations on which the TMDL is based. It additionally includes the public notice announcement, any public comments received, the Department's responses to those comments and files associated with the development of this revised and the original 2010 TMDL. This information is available upon request to the Department at dnr.mo.gov/sunshine-form.htm. The Department will process any request for information about this TMDL or amendment in accordance with Missouri's Sunshine Law (Chapter 610, RSMO) and the Department's administrative policies and procedures governing Sunshine Law requests. For more information about open record/Sunshine requests, please consult the Department's website at dnr.mo.gov/sunshinerequests.htm.

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Appendix A
Support for QUAL2K Model Assumptions

2010 Approved QUAL2K Model

Two point sources were represented in the 2010 QUAL2K model: the Lake Forest Estates Subdivision Wastewater Treatment Facility and the Indian Creek Tributary. The boundary of the 2010 model spanned for approximately two miles from near the confluence of Indian Creek with Establishment Creek to the spillway of Lake Anne. This methodology is inaccurate for two reasons: 1) Big Bottom Creek terminates at Indian Creek, so the impaired segment of Big Bottom Creek spans from the confluence of Big Bottom Creek with Indian Creek to the spillway of Lake Anne (1.47 miles), and 2) The 2010 model used Sample Point 3, which is located on Indian Creek downstream of the impaired segment, to represent the headwater in the QUAL2K Model. The use of a downstream sample point on Indian Creek inaccurately depicts both the headwater and the critical low flow condition of Big Bottom Creek because it is not located on or near the impaired segment. The headwater is more accurately represented by using data from the Lake Forest Estates Subdivision Wastewater Treatment effluent because there is no flow between the lake and the facility in dry months. Also, visual observations indicate that Big Bottom Creek is sometimes dry upstream of Indian Creek, so there is no effluent influence on Indian Creek during those times. The 2010 QUAL2K model used data from August 12, 2009, which is representative of the dry condition when effluent from the Lake Forest Estates Subdivision Wastewater Treatment Facility does not flow along the entire impaired segment. Therefore, data recorded on July 8, 2009, when there was continuous flow from the lake spillway to the confluence of Indian Creek were used as inputs for the 2019 revised model. Only Big Bottom Creek was modeled for the TMDL revision as it is the only waterbody not attaining uses. Because Big Bottom Creek terminates at Indian Creek, the Indian Creek tributary and the downstream Sample Point 3 from the original model were omitted during this revision. However, the critical condition model was carefully reviewed to ensure downstream attainment of the minimum dissolved oxygen criterion. As of the 2020 assessment for Clean Water Act 305(b) reporting, water quality data for Indian Creek indicate full attainment of the applicable aquatic life designated use. Therefore, any pollutant reductions determined in this TMDL as necessary for Big Bottom Creek will continue to be protective of downstream water quality in Indian Creek.

Existing Condition of Big Bottom Creek

Visual inspections of Big Bottom Creek during low flow conditions in 1995 and 2001 reported sludge deposits, green water, thick growths of prostrate algae, some filamentous algae, and a scarcity of aquatic life. Sludge deposits and green water are the result of improperly treated wastewater effluent. When wastewater effluent is improperly treated, biochemical oxygen demand, total suspended solids, and ammonia nitrogen concentrations are too high for the receiving stream to assimilate. Because Big Bottom Creek is impounded to form Lake Anne (formerly Lake Forest), the segment of the creek below the reservoir does not receive flow from the upstream portion and there is no flow over the dam during the summer. During low flow conditions, effluent from the Lake Forest Estates Subdivision Wastewater Treatment Facility constitutes the entire flow, and is therefore solely responsible for the water quality in the lower portion of Big Bottom Creek. Under these conditions, there is no rainfall or runoff to dilute the effluent or to transport suspended solids downstream for gradual deposition.

In addition to sludge deposits and green water, improperly treated effluent can result in deposition of organic solids (i.e., organic decomposable sediment) for some distance below the facility outfall. Observations that Big Bottom Creek is sometimes dry at its confluence with Indian Creek suggests that when effluent constitutes the entire flow, a zone of concentrated organic material may be created in the streambed where there is no flow to dilute or carry pollutants downstream through dispersion.

Prior visual inspections, and recent model calibration, suggest that benthic (i.e., bottom) algae cover approximately 80 percent of the streambed, and the area covered by decomposable material (sediment oxygen demand) is approximately 40 percent immediately downstream of the wastewater outfall. Model calibration with observed water quality data indicate that bottom algae coverage decreases to approximately 20 percent, and the area covered by decomposable material decreases to approximately five percent, near the sample point located one mile downstream. There is a marked difference in oxygen demand between Sample Point 1 (immediately downstream of the facility outfall) and Sample Point 2 (one mile downstream). This difference can be explained by both the high concentration of organic material and ammonia nitrogen in the wastewater effluent coupled with very low stream flows that do not provide dilution, reaeration, and dispersion. During times when effluent discharges constitute the only flow in Big Bottom Creek, concentrated organic material will be deposited a short distance downstream of the facility due to decreased velocities. These conditions result in low in-stream dissolved oxygen because the oxygen required for the decomposition of the concentrated organic material cannot be replenished fast enough through atmospheric oxygen exchange. Since there are no upstream flows and stream velocity is very low, there is little to no reaeration resulting from turbulence. In addition, the prolific presence of benthic algae causes notable “diel” fluctuations in dissolved oxygen concentrations. This means that the consumption of oxygen for the decomposition of organic material, including dead algal cells, causes low dissolved oxygen at night while daytime algal photosynthesis produces oxygen. This phenomenon is part of natural stream ecology; however, it is important, and required, that instream dissolved oxygen concentrations maintain a minimum of 5.0 mg/L at all times to protect aquatic life in warm water habitats.

2019 Revised QUAL2K Calibration Model

Multiple observations during low flow conditions (1995, 2001, 2004, 2005, 2006, and 2009) have found that water from Lake Anne does not flow to Big Bottom Creek between the lake spillway and the Lake Forest Estates Subdivision Wastewater Treatment Facility during low flow periods. Therefore, Lake Anne does not contribute pollutant loads during low flow periods when sludge deposits were visible. Water flows over the lake spillway only during high flow periods. The seasonal variation provided by lake water inputs during wetter months results in greater dilution, reaeration, and dispersion of wastewater effluent. During these periods, facility effluent is diluted and has less impact on the water quality and physical characteristics of Big Bottom Creek. During the August 2009 monitoring events, it was also noted that Big Bottom Creek was dry at its confluence with Indian Creek, but was flowing for some distance downstream of the Lake Forest Estates Subdivision Wastewater Treatment Facility. This indicates that during critical low flow conditions, effluent from the facility constitutes the entire flow in the lower portion of Big Bottom Creek from the facility to Indian Creek.

Because Big Bottom Creek above the facility is dry during low flow conditions, the inputs used for the headwater condition in the 2019 revised QUAL2K models (necessary for the model to run) were estimated. The headwater inputs are a combination of water quality data recorded at Sample Point 1

on July 8, 2009, and discharge monitoring report data from the Lake Forest Estates Subdivision Wastewater Treatment Facility recorded on the July 31, 2009. Headwater condition input data are summarized in Table A-1.

Table A-1. Data Used for 2019 Revised QUAL2K Calibration Model

Sample Point	Time	Flow (cms)	$CBOD_5$ (mg/L)	Nitrogen (mg/L)	Nitrate (mg/L)	DO (mg/L)	pH	Temp (°C)	TP (mg/L)
1	6:45 am	0.011	3.1	1.630	0.930	3.68	7.21	23.27	0.330
1	1:30 pm	0.030	5.2	0.897	0.397	4.64	7.21	26.08	0.0832
2	6:00 am	0.010	1.3	0.455	0.353	5.83	7.62	20.15	0.0667
2	12:50 am	0.060	2.7	0.264	0.297	8.08	7.40	23.92	0.0628
DMR	ND	0.0033	9.70	1.25	ND	7.70	7.50	24.2	0.330

Specific QUAL2K input values and data sources are presented in Table A-2, and point source inputs for the Lake Forest Estates Subdivision Wastewater Treatment Facility are presented in Table A-3. The inputs used provide the most conservative assumptions, and align the best-fit of the QUAL2K model to the observed data. Although water quality data show lower dissolved oxygen concentrations during the August 12 and 13, 2009 monitoring events, data from these dates could not be used in the QUAL2K model because there was no flow in Big Bottom Creek at Sample Point 2 on those days, and therefore no data recorded at Sample Point 2. Data recorded in the July 31, 2009 entry of the Lake Forest Estates Subdivision's discharge monitoring report were used for the point source inputs. The headwater inputs used are data recorded at Sample Point 1 on July 8, 2009, and discharge monitoring report data recorded on the July 31, 2009. The resulting calibration graphs for dissolved oxygen and biochemical oxygen demand are presented in Figures A-1 and A-2.

Table A-2. QUAL2K Calibration Model Headwater Inputs

Field	Value	Source
Flow Rate	0.0300 cubic meters per second	SP-1 at 1:30 pm
Temperature	26.08 °C	SP-1 at 1:30 pm
Dissolved Oxygen	3.68 mg/L	SP-1 at 6:45 am
CBODfast	9.70 mg/L	DMR
NH4-N (ammonia nitrogen)	1.250 mg/L	DMR
Organic Phosphorus	0.330 mg/L	SP-1 at 6:45 am
Alkalinity	25 mgCaCO3/L	Model default value
pH	7.5	DMR

Table A-3. QUAL2K Calibration Model Point Source Inputs

Field	Value	Source
Flow Rate	0.0033 cubic meters per second	DMR-0.075 Mgal/day
Temperature	24.20 °C	DMR
Inorganic Suspended Solids	19.0 mg/L	DMR
Dissolved Oxygen	7.70 mg/L	DMR
Fast CBOD	9.70 mg/L	DMR
Ammonia nitrogen	1.25 mg/L	DMR
Organic Phosphorus	0.330 mg/L	SP-1 at 6:45 am
Alkalinity	25 mgCaCO3/L	Model default value
pH	7.5	DMR

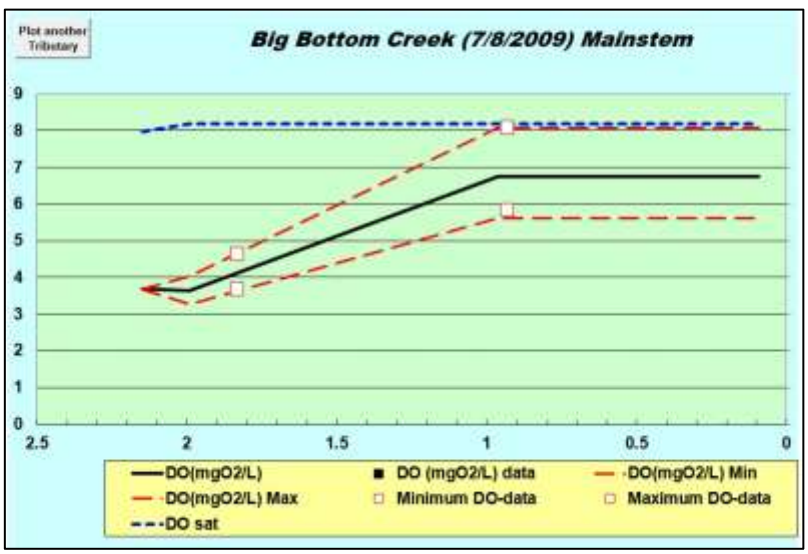

Figure A-1. QUAL2K Calibration Model – Dissolved Oxygen

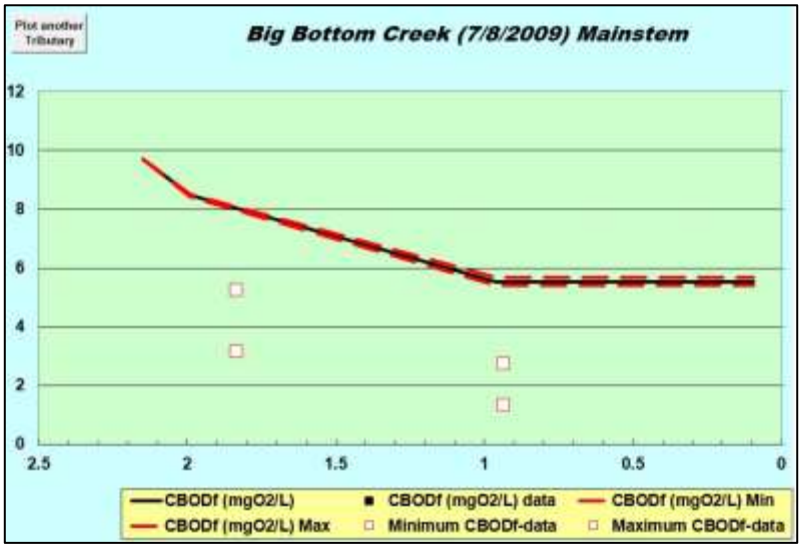

Figure A-2. QUAL2K Calibration Model – Biochemical Oxygen Demand

In-stream biochemical oxygen demand causes low in-stream dissolved oxygen concentrations. The QUAL2K model over-predicted the amount of oxygen demand exerted on Big Bottom Creek when the 9.70 mg/L biochemical oxygen demand (BODfast) reported in the Lake Forest Estates Subdivision discharge monitoring report was used as the point source input. The biochemical oxygen demand observed at Sample Point 1 on July 8, 2009, was 3.1 mg/L at 6:45 am and 5.2 mg/L at 1:30 pm. As presented in Figure A-4 in the next section, for the critical condition TMDL model when the point source biochemical oxygen demand was decreased to 5.0 mg/L, the QUAL2K model aligned with the observed water quality data.

2019 TMDL Wasteload Allocation QUAL2K Model under Low-Flow Condition

The rates and formulas assigned to calibrate the QUAL2K model were retained for the wasteload allocation model. Because the Lake Forest Estates Subdivision Wastewater Treatment Facility constitutes the entire flow in Big Bottom Creek below the Lake Anne spillway during critical low flows, the headwater and point source inputs are the same. In order to improve the condition of the impaired segment, biochemical oxygen demand, total suspended solids, and ammonia nitrogen in facility effluent must be reduced and maintained at lower concentrations. Specific input values are presented in Table A-3.

Table A-3. Input Values for Headwater and Point Source for the Wasteload Allocation Model

Field	Value	Source
Headwater - Flow Rate	0.0039 cubic meters per second	USGS StreamStats 7Q10 for downstream
Point Source – Flow Rate	0.0052 cubic meters per second	118,300 GPD facility design flow
Temperature	26.08 °C	SP-1 at 1:30 pm (7/8/2009)
Inorganic Suspended Solids	8.0 mg/L	Reduced WLA to reduce organic sediment deposition
Dissolved Oxygen	6.0 mg/L	Minimum to maintain 5.0 mg/L in stream

Fast CBOD	5.0 mg/L	Reduced WLA to reduce oxygen demand
Ammonia Nitrogen	1.0 mg/L	Reduced WLA to reduce oxygen demand
Organic Phosphorus	0.5 mg/L	Maximum to reduce bottom algae in streambed
Alkalinity	25 mgCaCO3/L	Model default value
pH	7.5	DMR

Expected Improvements to Big Bottom Creek

The wasteload allocations established in the 2019 Revised TMDL are expected to improve the condition of the portion of Big Bottom Creek located downstream of Lake Anne, and will result in the attainment of water quality criteria for dissolved oxygen, ammonia, and organic sediment. The wasteload allocations require a reduction in total suspended solids such that the effluent will not exceed 10.0 mg/L. According to the Lake Forest Estates Subdivision's discharge monitoring reports, past monthly total suspended solid discharges have ranged from as low as 6.0 mg/L to as high as 26 mg/L. Consistently limiting the amount of organic decomposable material that enters the stream will result in the reduction of in-stream oxygen demand over the entire length of the impaired segment, but will have the most positive effect on the stream immediately downstream of the facility. Limiting the amount of inorganic solids that enter the stream will improve instream habitat for aquatic life because the amount of foreign material deposition will be reduced. Reducing total suspended solids also corresponds to a reduction in total phosphorus because phosphorus binds readily with some types of inorganic sediment. Treatment techniques such as increasing effluent settling times and adding chemical flocculants will decrease the concentrations of both total suspended solids and total phosphorus in wastewater effluent. The QUAL2K model predicted compliance with the dissolved oxygen criterion of 5.0 mg/L when effluent total phosphorus is 0.5 mg/L. The wasteload allocations require reduction in ammonia nitrogen such that the effluent will not exceed a maximum 1.0 mg/L. The QUAL2K model predicted that in order for in-stream dissolved oxygen concentrations to remain above 5.0 mg/L, the maximum concentration that can be discharged when stream water temperatures may be as high as 26 °C is 1.0 mg/L ammonia nitrogen. Facility discharge monitoring reports show an approximate range of 1.2 to 6.1 mg/L for ammonia nitrogen. Consistently limiting the amount of ammonia nitrogen and soluble phosphorus that enters the stream is expected to result in a reduction in benthic algae growth. This will reduce the range of daily dissolved oxygen diel fluctuation such that the stream will achieve the minimum criterion of 5.0 mg/L at all times of day.

Based on the model inputs presented in the previous sections, the QUAL2K model predicts a dissolved oxygen concentration of 5.73 mg/L at Sample Point 1 just below the effluent outlet and 8.28 mg/L at Sample Point 2 near the confluence with Indian Creek. The dissolved oxygen and biochemical oxygen demand models are presented in Figures A-3 and A-4. As mentioned previously, consistently limiting the amount of ammonia nitrogen and soluble phosphorus that enters the stream is expected to result in reductions of benthic algae growth. Over time, the reductions in bottom algae and sediment oxygen demand will reduce the range of daily dissolved oxygen diel fluctuation. This means that the range between the minimum and maximum dissolved oxygen concentrations will narrow such that the stream will achieve the minimum criterion of 5.0 mg/L at all times of day.

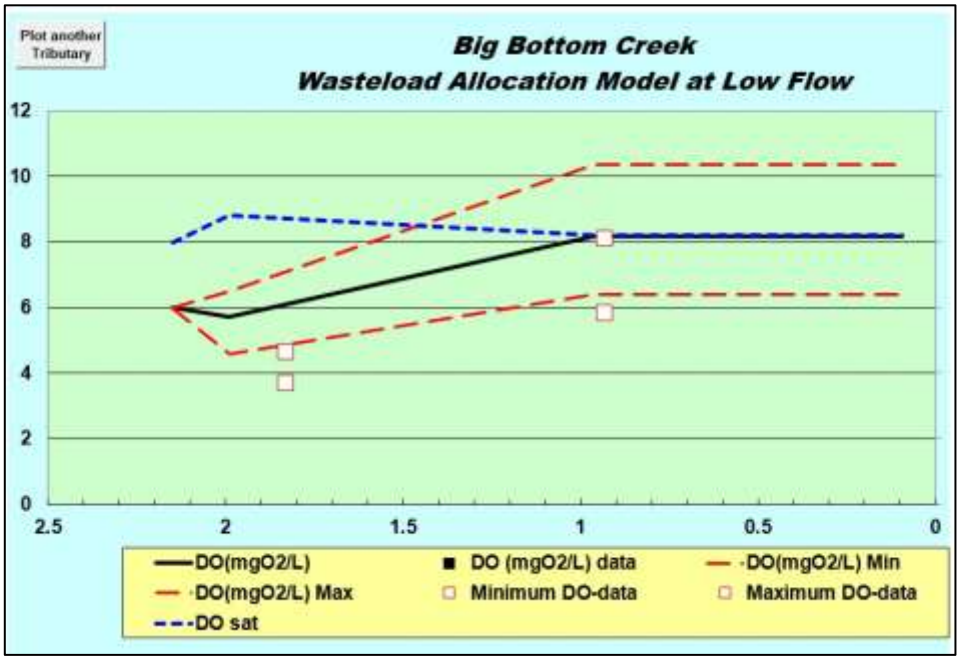

Figure A-3. Model-predicted Dissolved Oxygen with WLA at Low Flow

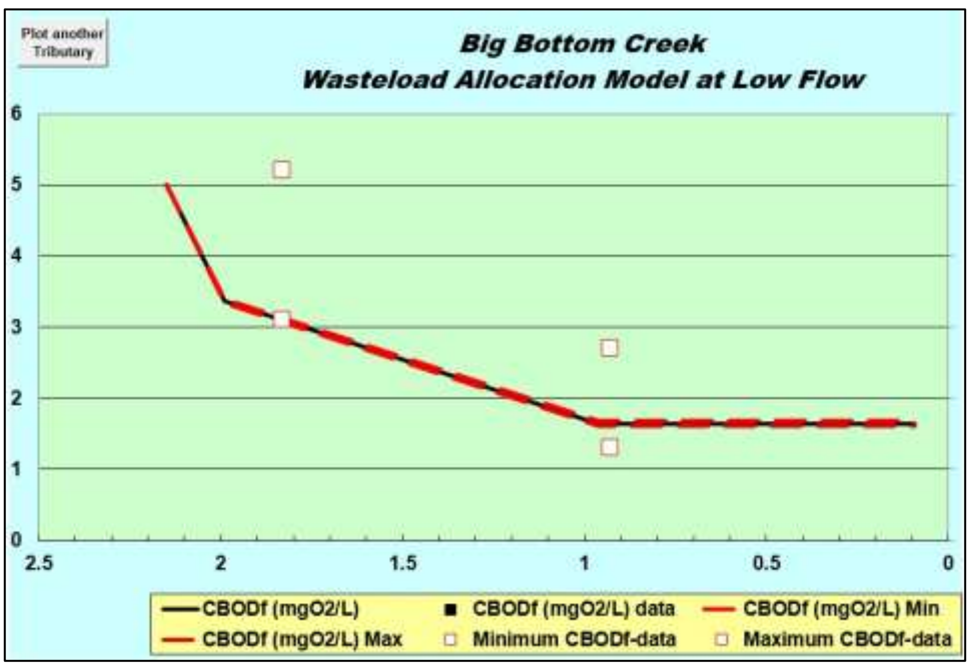

Figure A-4. Model-predicted Biochemical Oxygen Demand with WLA at Low Flow